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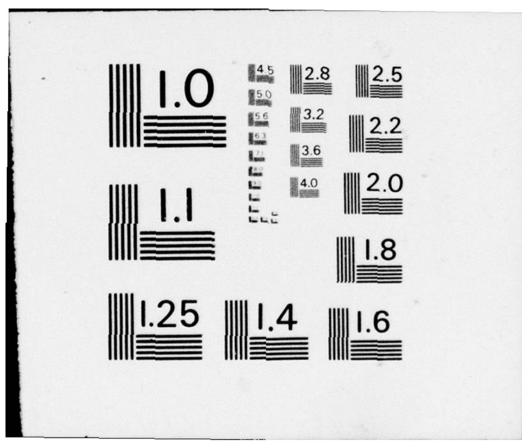
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PAYLOAD INSTRUMENTATION FOR PROBING ROCKETS

Martin J. Davin

Wentworth Institute
550 Huntington Avenue
Boston, Massachusetts 02115

30 April 1976

Final Report

(1 April 1973 - 31 March 1976)

Approved for public release; distribution unlimited.

AIR FORCE GEOPHYSICS LABORATORY
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This report summarizes the services supplied in support of the sounding rocket research program of the Air Force Geophysics Laboratory.

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WENTWORTH INSTITUTE

Final Report

Contract No. F19628-73-C-0232

I. INTRODUCTION

Contract No. F19628-73-C-0232 was initiated with Wentworth Institute on 1 April 1973 by the Air Force Cambridge Research Laboratories, Hanscom Air Force Base, Bedford, Massachusetts, (more recently re-designated as the Air Force Geophysics Laboratory, and referred to in this report, in passim, as AFGL) for participation in work on one of the many and varied phases of the Upper Atmosphere Research Program being conducted by the Air Force Systems Command of the United States Air Force. Its three-year period of performance was completed on 31 March 1976. It represented, essentially, a successor to Contract No. F19628-70-C-0229 which had been extant for substantially the same requirements and objectives during the period from 1 April 1970 to 31 March 1973.

II. SCOPE

The fundamental objective of the Upper Atmosphere Research Program is the acquisition of knowledge of the physical and chemical properties and phenomena of the vitally important upper atmospheric region by means of investigation, experimentation, and observations carried on through the medium of instrumentation installed in, and borne aloft by, probing rockets and other upper air vehicles.

As a part of that basic objective, this contract--which was carried on specifically with the Aerospace Instrumentation Laboratory of AFGL, and, more particularly, with the Research Probe Flight Branch of the Aerospace Laboratory--stipulated that Wentworth Institute provide the necessary personnel, facilities, services, and materials in connection with the adaptation of upper

air experiments to suitable vehicles as designated by that Laboratory. Basically, this included such phases as the development and construction of the instrumentation racks for the accommodation of the experimental apparatus being flown in the payload section of the rockets; the positioning and bracketing of all components; the mounting of various appendages on the skin of the vehicle for sensing devices, and the assembly of all supporting cables and circuitry required for the operation of the flight apparatus, per se, as well as ground-based electro-mechanical equipment essential to the support of the project involved. Also included were the fabrication and assembly of all special devices necessary for the proper functioning of the equipment peculiar to the experiment being flown in the rocket. Provision was made, in turn, for participation by the contract personnel in the field operations associated with the assembly, preparation, and launching of the experimental rockets at the different sites selected by the Laboratory. The preparation of all necessary and supporting electro-mechanical drawings, as well as graphs, charts, reports, and other visual aids pertinent to rocket-borne experiments was also included in the contractual requirements.

III. DESCRIPTION OF WORK

There were certain primary considerations in this particular research program which were, inherently, within the purview of the Air Force Geophysics Laboratory. These included such factors as the nature, purpose, scope, and objectives of the experiments to be conducted, the phenomena to be investigated, the parameters to be measured, the schedules for completion of the equipment and the launching, as well as the necessary coordination and liaison between the participating agencies and contractors. Further, the interpretation, analysis, evaluation, and eventual application of the diverse data obtained

from the rocket-borne experiments were likewise within the province of that facility, and, more particularly, the various Laboratories and their Branches immediately concerned with the experiments. In turn, the post-analyses of the performances and functions of the rocket system, per se, were also under the jurisdiction of the Aerospace Instrumentation Laboratory.

However, within the stipulated scope of this contract, and through close coordination and liaison with the contract monitor and the project engineers and scientists immediately concerned with the electro-mechanical design features of the apparatus and the theoretical aspects of the experiments, respectively, services, materials, and facilities were provided for each project, or its germane supporting tasks, from the preliminary discussion stages--through the design/development, fabrication, assembly, installation, and test processes--to the delivery of the completed units, or, when required, to the crating and shipping of the instrumentation to the launch site specified by the cognizant Laboratory. At the launch sites, in turn, the contract personnel participated with AFGL members and representatives from other concerned agencies in the pre-flight assembly, installation, and testing of the apparatus, as well as in the flight and post-flight operations.

The primary functions performed under this contract were those directly concerned with the design, layout, fabrication, assembly, installation, and testing of the components comprising the payloads for the various rocket-borne experiments undertaken by the AFGL. Each of these tasks differed--in both magnitude and degree of complexity and sophistication--in consonance with the nature and purpose of the basic experiment or flight objective and in accordance with the type of rocket selected by the Laboratory to carry aloft the experimental equipment. In those instances where the same type of rocket was utilized for the same basic study through a series of launchings conducted

over an extended period of time, the steps and procedures followed in the construction of the instrumentation rack and the modification of the nose cone to accommodate the scientific apparatus were essentially the same; nevertheless, even in those cases, certain changes were incorporated in succeeding assemblies in varying degrees as a result of knowledge gained from a prior firing, thus effecting a more stable and efficient performance with the ultimate aim being the acquisition of more and reliable data of a greater degree of relevancy.

Following the actual determination by the Laboratory as to the experiment to be flown and the type of probing rocket best accommodative to carry it, a typical contractual project commenced with close coordination between the Institute's Design and Electronics Sections and the Laboratory's representatives. From this initial phase, and utilizing any available data and knowledge obtained from past rocket flight performances germane to the particular experiment involved, there would evolve the various detail and assembly drawings required for the electro-mechanical components and sub-systems comprising the instrumentation system and the payload. These encompassed all design features for the basic instrumentation rack, the method of installing and mounting the diverse components comprising the payload members, and the necessary details for the modification of the rocket nose cone in order to make it compatible with, and accommodative for, the experimental equipment per se, as well as the various schematics and diagrams required for the circuitry for the experiment. After the checking and subsequent reproduction of the drawings, they were distributed to the Missile Laboratory and Electronics Section for the initiation of the actual fabrication and assembly stages. Concurrent with this action was the placement of orders for the procurement of the necessary stock, hardware, and commercial mechanical and electrical components specified for the construction and assembly processes. As these phases proceeded, periodic discussions

were held between Laboratory representatives and contract personnel not only with regard to the progress of the project in toto--in view of the assignment of specific dates for assembly completion, tests, shipping, pre-launch period, and launch--but in connection with any possible assembly difficulties being encountered or modifications of design being required when newly-fabricated parts are being assembled for the first time.

The nature of the process was such that in many instances certain of the electronics work could not be commenced until portions of the basic payload instrumentation rack and other mechanical components had been completed by the Missile Laboratory; on the other hand, wherever possible, sub-assemblies were prepared as soon as the circuitry requirements and specifications were determined. Cables and harnesses were also prepared in advance whenever possible. After the assembly of the mechanical and electrical phases, the equipment was subjected to a series of tests and checks by Laboratory and contract personnel; certain of these tests were performed at the Institute's facilities, while others, because of the requirement for special equipment, were conducted at the Air Force Geophysics Laboratory. Upon the completion of these tests--and after the incorporation of any modifications, both mechanical and electrical, which were deemed necessary as a result of the checks--the equipment was packed in appropriately-assembled boxes and then shipped to the launch site designated by the Aerospace Instrumentation Laboratory.

In practically all cases, a member of the Institute's contract group travelled to the launch site to participate in the pre-flight, flight, and post-flight field operations with members of the AFGL and other concerned agencies. On some occasions, two or three members, in combinations from the Design Section and the Electronics Section, would take part in the launch operations, depending upon the complexity of the rocket-borne experiment

involved, the number of vehicles in a series, and the scope of the duties and activities delineated for completion at the site itself.

In view of the fact, as already noted, that the fundamental schemata were evolved by, and emanated from, the cognizant Laboratory of the Air Force Geophysics Laboratory--and inasmuch as the definitive data and pertinent information from the various related and sequential steps of the projects, from the planning stages through the operating and concluding steps, were progressively accumulated, recorded, evaluated, and utilized by that facility--this report will constitute a brief over-all summary, focused, in chronological order, and in quasi-historical format, upon major projects or tasks indicative of the basic objectives of the contract, rather than a detailed description of the technical aspects of the many and varied processes following in the Design Section, the Missile Laboratory, and the Electronics Section.

During the period from the commencement of the contract on 1 April 1973 to 31 December 1973, a total of eleven man-trips was made, comprising eight to the launch site at White Sands Missile Range, New Mexico, and three to the Barreira do Inferno Range near Natal, Brazil.

The first of the WSMR trips was concerned with the field operations associated with the launch of two Ute-Tomahawk Rockets bearing Nos. A09.102-1 and A09.209-1. These vehicles were instrumented to measure O_2, O_3, and infrared profile with optical sensors. The basic payload installations included scientific sensors; two (2) doors with ejection mechanisms; two telemetry systems including antennas; a C-Band radar beacon including antennas, with timers, batteries, and associated wiring harnesses. Rocket No. A09.209-1 also carried a Range Receiver. These two rockets were launched on 16 April. One contract member was at the site from 4 to 17 April. The second trip to WSMR was associated with the launch of an Aerobee 150 Rocket, No. A03.211-1,

on 10 August. The flight objective was the measurement of atmospheric density with the use of bremsstrahlung generated by an electron beam. The installations included the cone-cylinder, with electron guns, photometers, proportional counters, timers, associated batteries and wiring harnesses, two instrument umbilical plugs, and magnetometers. One contract member was at the launch area from 29 July to 12 August.

On 30 September, three contract members travelled to WSMR to take part in the scheduled launch of an Aerobee 350 Rocket, No. A35.191-2, as the initial phase under Project Hi-Hi Star. Some equipment problems were encountered, with a resultant postponement of the flight; the personnel returned from WSMR on 16 October. One member re-visited the site from 28 November to 3 December, while the seventh and eighth man-trips were made from 13 to 19 December for the same scheduled experiment.

The first two man-trips to the Barreira do Inferno Range extended from 10 to 29 May 1973. They were concerned with the launch of a Castor-Lance Rocket No. A44.320-1 (MKV-1). The payload for this vehicle consisted of the nose cone with a 33-lb. tip for ballast, and batteries for the sensor, ACS, support section and ordnance; a liquid helium cooled scanning radiometer and a releasable door; a yo-yo design despin unit; support apparatus comprising telemetry, radar beacon, batteries for the TM and beacon, commutator, timer, control circuits, umbilicals, and antennas; the Attitude Control System with control jets and nitrogen gas supply, and a Marman clamp separation system. This was followed by a transition section designed to effect a smooth transition between the 11-inch payload diameter and the diameter of the 15-inch Lance rocket. This vehicle, which had as its basic objective the measurement of the position and intensity of infrared emitting layers in the upper atmosphere, was successfully launched on 25 May. The third man-trip to

the Natal range was associated with the flight of a Paiute-Tomahawk Rocket bearing No. A10.306-1. This rocket, which was instrumented for the measurement of equatorial density as a part of a series of rocket-borne experiments being conducted at Natal, was launched on 26 September. The contract member was at the site from 4 September to 1 October 1973.

During 1974, a total of 25 man-trips was made, comprising 18 to White Sands Missile Range, two the NASA Station at Wallops Island, Virginia, and five to Woomera, Australia. These are discussed here in the above site order, as are the launch projects consummated at the various ranges during 1975 and the first quarter of 1976.

The first three man-trips to WSMR, from 7 to 28 January 1974, were related to the rescheduled launch of Aerobee Rocket No. A35.191-2, which, as noted earlier, had been postponed. However, electrical problems caused a further delay, with a rescheduling for approximately mid-February.

The fourth man-trip to WSMR took place from 17 to 27 January for the scheduled launch of a Ute-Tomahawk Rocket, No. A09.400-1. However, it was necessary that the flight be postponed and rescheduled.

The next three trips to that range were concerned with the rescheduled Aerobee No. A35.191-2. This flight was conducted on 16 February. The objective of this experiment, the first of the Hi-Hi Star Project series, was the investigation of the natural radiation which is emitted by the celestial sphere. The payload installations consisted of the following: (a) the Nose Cone with the Hi-Hi Star sensor, ACS pneumatics and support systems, and pitch, yaw, and roll jets; (b) Telemetry Section with Link I using a circumferential slot antenna, and with a C-band beacon; (c) the ACS, with gyros, associated support system, and the umbilical; (d) the Recovery Section, with parachute system, severance ring, and drogue plate ejection; (e) Sustainer Section, with range

safety command receiver, quadraloop antennas, and yo-yo despin, and (f) the Tail Section with a distribution box and the squib-operated oxidizer and fuel cut-off valves. The three contract members were at the range from 7 to 18 February.

The eighth trip to WSMR, from 12 to 17 February, was concerned with the rescheduled launch of the Ute-Tomahawk Rocket No. A09.400-1. This vehicle, which was instrumented for the study of atmospheric density as a function of altitude within the range of 30 to above 100 Km, was launched on the same date as the Aerobee No. A35.191-2, namely, 16 February. This payload carried a 10" diameter sphere, with a coherent beacon, for ejection from the rocket at an altitude of approximately 160,000 ft. on the upleg of the trajectory. Installations also included the split nose cone and sphere ejection mechanisms; the rocket radar beacon and antennas; an S-band TM system with diagnostic instrumentation and antenna, and associated batteries and wiring harnesses.

During the first four months of 1974, extensive efforts were directed towards the preparation of three payloads being assembled for Project Hi-Star South in Aerobee 200 Rockets Nos. A05.391-1, -2, and -3. After a series of mechanical integration and system tests for these units, the equipment for Nos. A05.391-1 and -3 was shipped to White Sands Missile Range on 6 May for balancing tests. Three contract members were at that site from 9 to 23 May. Three additional man-trips were next made to that range, from 19 to 28 June, for tests of the No. A05.391-2 payload. While there, the members took part in the assembly and crating of the flight equipment and associated accessories for shipment to Travis Air Force Base, California, from which point it was transshipped to Woomera, Australia.

During the period from 15 to 25 August, two contract members were at WSMR to take part in the scheduled launch of a Nike-Hydac rocket under Project

PRECEDE. Unfavorable weather conditions caused a postponement of this flight, and it was rescheduled for mid-October. The final two man-trips to that range in 1974 were made for that rescheduled launch during the period from 12 to 19 October. This payload encompassed several distinctive mechanical functions during flight. It had a 12" split nose cone which was separated after a cap was revoved from an electron gun, thus exposing the gun. On the skin structure there were four doors which were blown off, thereby exposing instruments. Two of the doors, opposite each other, were ejected, allowing an ion trap and RPA instrument to "look" out. A third door was then blown off, allowing a slide, which held five photometers, to extend out beyond the surface of the skin and lock in position. The fourth and last door was blown off to allow an impedance probe to fold down and take a position of 90° with respect to the payload spin axis. To support all of this equipment, a new nose cone separation mechanism was designed, as was a carriage slide for holding the photometers.

During the period from 3 June to 1 July 1974, two contract members were at Wallops Island, Virginia, to take part in the launch operations for two of the many rockets which had been assembled by the Air Force Geophysics Laboratory as a part of Project ALADDIN 74. This extensive program (Atmospheric Layering And Density Distribution of Ions and Neutrals) had as its primary objective the study of the atmospheric structure and dynamics in the upper atmosphere between 70 and 160 Km. Rocket No. A08.306-4, containing a 10" sphere, was launched on 29 June, while Rocket No. A10.309-2, containing a 7" sphere, was launched on 30 June.

The first three of the five man-trips to Woomera, Australia, for Project Hi-Star South, took place from 8 August to 12 September 1974. Rocket No. A05.391-1 was launched on 4 September. Two additional contract members were at the site from 3 to 24 September. Rocket No. A05-391-2 was launched on 11 September,

while No. A05.391-3 was launched on 17 September. Aerobee 200 vehicles, with a NIKE booster, were used for these flights. The installations comprised the following: Cone: ejectable split cone, fine guidance sensor, stellar aspect sensor, and small ejectable door; Casting: Hi-Star South sensor, gimbal drive mechanism, nitrogen purge umbilical, and two large ejectable doors; Support Section: sensor off-gimbal electronics, power supplies, timing, and logic and control circuits, telemetry transmitter, and C-band radar beacon; ACS: gyros, associated support system, and umbilical; Pneumatics: pneumatic support systems, compressed nitrogen tank, roll jets, and nitrogen fill umbilical; Recovery: parachute recovery system, severance ring, and pitch and yaw jets; Forward Skirt: yo-yo despin, and Tail Section with distribution box and squib-operated oxidizer. The objective of the experiment was the investigation of the natural radiation which is emitted by the celestial sphere in the southern hemisphere.

During 1975, a total of nine man-trips was made, comprising six to White Sands Missile Range, one to Poker Flat Rocket Range, Alaska, and two to Fort Churchill Research Range, Manitoba, Canada.

The first two of the six trips to WSMR took place from 2 to 11 June for participation in the launch of the Aerobee 150 Rocket bearing No. A03.103-1. This vehicle, with instruments for atmospheric density studies, was successfully launched on 9 June. The third man-trip to this range, during the period from 28 July to 8 August, was related to the pre-flight, flight, and post-flight operations for an Aerobee 170 Rocket designated as No. A04.308-1. This vehicle, which was also instrumented for atmospheric density studies, was launched on 6 August.

One contract member was at WSMR from 6 to 17 October to take part in the field operations for the flight of a Paiute-Tomahawk Rocket, No. A10.000-2 for a dispersion control test. This vehicle was successfully launched on 17 October.

During the second and third quarters of 1975, as well as a portion of the fourth period, extensive activities were directed towards the preparation of the payload for the Aerobee 350 No. A35.191-1 for the Super Hi-Star Project. Following a repetition of a series of tests and checks at Wentworth Institute and at the AFGL complex, the payload and support equipment was prepared for shipment to White Sands Missile Range. The basic installations comprised the following: (a) Cone Cylinder with Hi-Star sensor, stellar aspect sensor, guidance error sensor, three ejectable doors, ejectable nose cone, associated support systems, and umbilicals; (b) Telemetry; (c) ACS, with gyros, support system, and umbilical; (d) Pneumatics, with support systems, compressed nitrogen tank, and roll jets; (e) Recovery Systems, and (f) Separation and Despin units. This vehicle, which had as its objective the investigation of natural radiation which is emitted by the celestial sphere, was launched on 3 December 1975. Two contract members were at the site from 18 November to 5 December.

The one man-trip to the Poker Flat Rocket Range, Alaska, during 1975, took place during the period from 18 February to 2 March for participation in certain of the pre-flight operations associated with Project MULTI III. This Hydac rocket was successfully launched at a later date by AFGL.

The two man-trips to the Fort Churchill Research Range were associated with the launch of two Paiute-Tomahawk Rockets, Nos. A10.403-3 and A10.302-1. These represented two of nine vehicles which had been scheduled for flight as a part of Exercise PARADISE AEOLUS (Auroral Excitation of Oscillation and Layering of the Underlying Species) which was conducted by AFGL at that range. The basic purpose of this Exercise, during which the nine rockets were launched in three groups of three each, was the investigation of the dynamical properties of the auroral zone atmosphere in a coordinated rocket and ground-based program designed to characterize the differences between geomagnetic quiet and disturbed and aurorally active times. Rocket No. A10.403-3 was launched on 10 April,

while Rocket No. A10.302-1 was launched on 21 April. Two contract personnel were at the research range from 25 March to 22 April.

During the final quarter of this contract, that is, from 1 January to 31 March 1976, two contract members took part in various phases of the operations for two launches conducted by the Air Force Geophysics Laboratory at Poker Flat Rocket Range. One assignment was associated with pre-launch operations for Project HIRIS Reflight during the period from 9 to 22 February. The second, during the period from 10 February to 4 March, was concerned with certain phases of the flight activities for a Paiute-Tomahawk Rocket bearing No. A10.507-1. This experiment, which had as its objective the study of the atmospheric density and temperature in the altitude range of 40 to 140 Km under disturbed ionospheric conditions, was launched on 3 March.

Reference is made here to three Scientific Reports which were written and published during the tenure of this contract.

The first report, No. AFCRL-TR-75-0108, dated 1 April 1974, is entitled "Support Devices for Sounding Rocket Instrumentation Systems." It describes a Universal Time Delay (UTD) and an Automatic Test System (ATS). The UTD was designed and developed to serve as a supplementary timing device to cope with the requirement for more payload timer outputs stemming from the ever-increasing complexity of sounding rocket payloads. The ATS was developed to accommodate and perform the increased number of times it is necessary to conduct battery charge/discharge tests as a result of the change-over from Silvercel to Nicad batteries for use as power sources in sounding rocket payloads.

The second report, "A Capacitor Discharge Squib Firing Unit," dated 1 April 1975 and bearing No. AFCRL-TR-75-0620, describes the design and development of a capacitor discharge (CD) ignition system. Design objectives included simultaneous four-bridgewire firing capability, one-second recovery, 0.5A supply

drain, and three outputs. A +28 VDC supply is required. A +28 volt firing command closes a selected firing relay for 30 ms; at 20 ms, the firing capacitors are discharged into the squib circuit through an SCR. This unit includes standard safety features (ARM/SAFE relay and 100 k-ohm squib isolation), and monitors for both capacitor voltage and squib current.

The third report, entitled "Rocket-Borne IR Sensor Deployment System," dated 31 March 1976, and assigned No. AFGL-TR-76-0125, describes the design and development of a control system for the deployment of an IR Sensor. The control system contained a Logic Control Unit which received four input commands, viz., "Logic Reset", "Deploy", "Step", and "Stow", from the ACS and Payload Programmer. Upon receiving these commands, the Logic Control Unit would integrate input information from a 40° Enable Switch, Direction Monitor, and Shaft Position Encoder, and generate six control functions for the control relays. These relays control the modes of operation of a Jack Mechanism, a Gimbal Drive Assembly, and a Gimbal Brake Assembly. The resultant control system provided a Sensor Deployment Program, under Normal Operation, and a Failsafe Program under Failsafe Operation.

IV. CONCLUSION

The foregoing section of this report, as had been forecast on Page 8, represents a brief over-all summary, focused, in chronological order, and in quasi-historical format, upon major activities indicative of the basic aims and accomplishments of the contract. As has also been noted earlier, no attempt has been made to repeat a detailed description of the technical aspects of the many and varied processes followed in the Design Section, the Missile Laboratory, and the Electronics Section. As was also mentioned, the definitive data and pertinent information obtained from the various experiments was evaluated and utilized by the Air Force Geophysics Laboratory at the time of its generation.

Similarly, no attempt has been made to cite, in detail, the many small supporting, yet essential and germane, tasks undertaken in both the electrical and mechanical phases of the work, especially the type which represented modifications of units at various stages of their fabrication and assembly. These are considered "standard procedure" in any endeavor encompassing new experimental units and prototypes, as well as in the processes involved in the modifications of existing components in an effort to eliminate any possibility of malfunction and to increase their operational capabilities, all with the aim of acquiring more meaningful and reliable data. In like manner, no detailed delineation has been made of the many drawings which were prepared, and subsequently modified and up-dated, as a result of the many necessary changes in mechanical design, wiring procedures, component installation, etc. These, too, are considered normal requirements in this type of developmental activity.